Executive Summary

The fiscal year ending September 2014 (FY14) concluded the first 18 months of the fourth five-year renewal of Cooperative Agreement DE-NA0001944 with the U.S. Department of Energy (DOE). This annual report summarizes work carried out under the Cooperative Agreement at the Laboratory for Laser Energetics (LLE) during the past fiscal year including work on the Inertial Confinement Fusion (ICF) Campaign; laser, optical materials, and advanced technology development; operation of the Omega Laser Facility for the ICF and High-Energy-Density (HED) Campaigns, the National Laser Users' Facility (NLUF), the Laboratory Basic Science (LBS) Program, and other external users; and programs focusing on the education of high school, undergraduate, and graduate students during the year.

Inertial Confinement Fusion Research

One of LLE's principal missions is to conduct research in ICF with particular emphasis on supporting the goal of achieving ignition on the National Ignition Facility (NIF). This program uses the Omega Laser Facility and the full experimental, theoretical, and engineering resources of the laboratory. During FY14, a record total of 2104 target shots were taken at the Omega Laser Facility (comprised of the 60-beam OMEGA UV laser and the four-beam, high-energy petawatt OMEGA EP laser). More than 42% of the facility's target shots in FY14 were designated as ICF experiments or experiments in support of ICF. The OMEGA and OMEGA EP lasers attained average experimental effectiveness of 93.3% and 92.8%, respectively, in FY14.

LLE plays a lead role in validating the performance of cryogenic target implosions, essential to all forms of ICF ignition. LLE is responsible for a number of critical elements within the Integrated Experimental Teams that support the demonstration of indirect-drive ignition on the NIF and is the lead laboratory for the validation of the polar-direct-drive (PDD) approach to ignition on the NIF. LLE has also developed, tested, and constructed a number of diagnostics that are being used at both the Omega Laser Facility and the NIF. During this past year, progress in the inertial fusion research program continued in three principal areas: ICF experiments and experiments in support of ICF; theoretical analysis and design efforts aimed at improving direct-drive–ignition capsule designs (including polar-direct-drive–ignition designs) and advanced ignition concepts such as shock ignition and fast ignition; and development of diagnostics for experiments on the NIF, OMEGA, and OMEGA EP.

1. Inertial Confinement Fusion Experiments in FY14

The physics of direct-drive implosions that are hydrodynamically equivalent to ignition designs on the NIF were studied on the OMEGA Laser System and reported in an article on p. 18. It is shown that the highest hot-spot pressures (up to 40 Gbar) are achieved in moderate-fuel-adiabat ($\alpha \sim 4$) target designs, which are well understood using 2-D hydrocode simulations. The performance of lower-adiabat implosions is significantly degraded relative to the code predictions, and simplified theoretical models are developed to gain a physical understanding of the implosion dynamics that dictate the target performance.

In an article on p. 58, the experimental evidence for multibeam laser–plasma instabilities of relevance to laser-driven ICF at the ignition scale is reviewed for both the indirect- and direct-drive approaches. The instabilities described are cross-beam energy transfer (CBET), multibeam stimulated Raman scattering, and multibeam two-plasmon–decay instability. Advances in theoretical understanding and the numerical modeling of these multibeam instabilities are discussed.

A novel experimental method that is used to measure key physical properties for fibers used to mount cryogenic implosion targets is reported in an article on p. 103. Young's modulus and the critical damping ratio of such fibers, at temperatures from 295 K to 20 K, are needed to design stable targets that are required for high-yield implosions, but these property values do not exist in the literature. The method described enables one to accurately measure the properties of interest for fiber diameters as small as 12 μm at ~20 K, and measurements are reported for fibers made of the following materials: Nicalon™ ceramic grade [silicon carbide (SiC)], Zylon®HM {poly[p-phenlyne-

2,6-benzobisoxazole] (PBO)}, M5 {dimidazo-pyridinylene [dihydroxy] phenylene (PIPD)}, and polyimide.

Radiography with ~10- to 50-MeV protons is used to investigate electric and self-generated magnetic fields in direct-drive–implosion experiments at the Omega Laser Facility (p. 110). The experiments used plastic-shell targets with imposed surface defects to enhance self-generated fields. The proton radiographs show multiple ring-like structures produced by electric fields of ~10^7 V/cm, as well as fine structures from surface defects, indicating self-generated fields up to ~3 MG. These electric and magnetic fields show good agreement with 2-D magnetohydrodynamic simulations.

The equation of state (EOS) and optical reflectivity of shock-compressed polystyrene (CH) are measured up to the unprecedented high pressure of 62 Mbar along the principal Hugoniot (p. 142). The results from a first-principles quantum molecular dynamics (QMD) method are compared with existing experimental measurements as well as the *SESAME* EOS model. The predicted pressure/temperature and optical reflectivity of shocked CH from QMD calculations agree well with experiments for pressures below 10 Mbar; above 10 Mbar, the QMD-predicted polystyrene is stiffer than that predicted by the *SESAME* model.

Two approaches to increasing the ablation pressure are demonstrated (p. 158) that can help to achieve implosion performance on the OMEGA laser, which is hydrodynamically scalable to ignition on the NIF. A target design that uses a Be ablator is shown to increase the hydrodynamic efficiency, resulting in a ~10% increase in the ablation pressure, compared to the standard CH ablator. Reducing the beam size is shown to recover all of the ablation pressure lost to CBET, but the illumination uniformity reduces the integrated target performance. The hydrodynamic efficiency is measured for the current cryogenic design, multiple ablator material design, and various beam focal-spot sizes.

Measurements of pressure and fuel–shell mix in compressed isobaric hydrogen implosion cores using x-ray continuum are described (p. 166). The x-ray emissivity depends almost entirely on the pressure when measured within a restricted spectral range. In this way, the measured free–free emissivity profile becomes a direct measure of the hot-core pressure at the time of peak emission. A simple scaling of the total filtered x-ray emission as a constant power of the total neutron yield is explained. The hot-spot "fuel–shell" mix mass can be inferred by attributing the excess emission to the higher emissivity of shell carbon mixed into the implosion's central hot spot.

Picosecond time-resolved, monochromatic 8-keV x-ray radiographic measurements of imploded cone-in-shell targets on OMEGA are reported on p. 191. They provide for the first time a detailed quantitative study of the hydrodynamic evolution of nonsymmetrically imploded, high-density matter up to peak compression. This work is an important step forward for fast ignition because it demonstrates that sufficient areal density can be compressed in nonspherical implosions to stop that part of the fast-electron spectrum (~mega-electron volt) that is relevant for fast ignition.

The first experimental demonstration of the capability to launch shocks of several-hundred Mbars in spherical targets—a milestone for shock ignition—is reported beginning on p. 213. Using the temporal delay between launching the strong shock at the outer surface of the spherical target and the time when the shock converges at the center, the shock-launching pressure can be inferred using radiation–hydrodynamic simulations. Peak ablation pressures exceeding 300 Mbar are inferred at absorbed laser intensities of ~3×10^{15} W/cm^2. The shock strength is shown to be significantly enhanced by coupling suprathermal electrons with a total converted energy of up to 8% of the incident laser energy. At the end of the laser pulse, the shock pressure is estimated to exceed ~1 Gbar because of convergence effects.

Studies of the channeling of multikilojoule high-intensity laser beams in an inhomogeneous plasma are reported (p. 233). Experiments have been performed that investigate the transport of high-intensity (>10^{18} W/cm^2) laser light through a millimeter-sized, inhomogenous, kilojoule, laser-produced plasma up to overcritical density. The high-intensity light evacuates a conical-shaped cavity with a radial parabolic density profile that is observed using a novel optical probing technique—angular filter refractometery. The experiments showed that 100-ps infrared pulses with a peak intensity of ~1×10^{19} W/cm^2 produced a channel to plasma densities beyond critical, while 10-ps pulses with the same energy but higher intensity did not propagate as far. The plasma cavity forms in less than 100 ps, using a 20-TW laser pulse, and advances at a velocity of ~3 μm/ps, consistent with a ponderomotive hole-boring model.

A study of the dependence of tritium release on temperature and water vapor from stainless steel is reported (p. 238). In general, increasing either the sample temperature or the relative humidity causes an increased quantity of tritium to be removed. Increasing the temperature to 300°C in a dry gas stream results in a significant release of tritium and is, therefore, an effective means for reducing the tritium inventory in steel. For humid purges at 30°C, a sixfold increase in humidity results in a tenfold increase in the peak outgassing rate. Increasing the relative humidity from 0% to 20% when the sample temperature is 100°C causes a significant increase in the tritium outgassing rate. Finally, a simple calculation shows that more activity is available than is actually removed in an experiment, suggesting that the surface oxide acts as a barrier to tritium removal.

2. Theoretical Design and Analysis

We report (p. 1) on the development of the theory of hydrodynamic similarity, which is used to scale the performance of direct-drive cryogenic implosions conducted at the Omega Laser Facility to NIF energy scales. The theory of hydrodynamic similarity is tested with hydrodynamic simulations and is then used to determine the requirements for demonstrating hydro-equivalent ignition (implosions with the same implosion velocity, adiabat, and laser intensity) on OMEGA. Hydro-equivalent ignition on OMEGA is represented by a cryogenic implosion that would scale to ignition on the NIF at 1.8 MJ of laser energy symmetrically illuminating the target. It is found that a reasonable combination of neutron yield and areal density for OMEGA hydro-equivalent ignition is 3 to 6×10^{13} and ~0.3 g/cm^2, respectively, depending on the level of laser imprinting.

New QMD calculations for the thermal conductivity (κ) of deuterium, over the broad density (ρ = 1.0 to ~700 g/cm^3) and temperature ($T = 5 \times 10^3$ K to $T = 8 \times 10^6$ K) conditions undergone by ICF imploding fuel shells are presented (p. 1). Over the wide ranges of conditions in such coupled and degenerate plasmas, the extensively used Spitzer model and a variety of other thermal conductivity models break down. The differences resulting from the use of κ_{QMD} are shown to be particularly relevant for lower-adiabat implosions and shell conditions during the early stages of an implosion.

The linear stability for multiple coherent laser beams is studied with respect to the two-plasmon–decay instability in an inhomogeneous plasma in three dimensions (p. 129). Cooperation between beams leads to absolute instability of long-wavelength decays, while shorter-wavelength shared waves are shown to saturate convectively. Nonlinear calculations show that Langmuir turbulence created by the absolute instability modifies the convective saturation of the shorter-wavelength modes, which are seen to dominate at late times.

Direct-drive–ignition designs with mid-Z ablators are presented (p. 220). Ablator materials of moderate atomic number Z reduce the detrimental effects of laser–plasma instabilities in direct-drive implosions. To validate the physics of moderate-Z ablator materials for ignition target designs at the NIF, hydro-equivalent targets are designed using pure plastic, high-density carbon, and glass ablators. The hydrodynamic stability of these targets is investigated through 2-D single-mode and multimode simulations. The overall stability of these targets to laser imprint perturbations and low-mode asymmetries allows for the development of high-gain target designs using uniform illumination. Designs using polar-drive illumination are developed within the NIF Laser System specifications. Mid-Z ablator targets are attractive candidates for direct-drive–ignition designs since they present better overall performances than plastic ablators through reduced laser–plasma instabilities and a similar hydrodynamic stability.

3. Diagnostics

An article on p. 50 reports on angular filter refractometry (AFR), a novel diagnostic technique that has been developed and used on OMEGA EP to characterize high-density, long-scale-length plasmas relevant to high-energy-density physics experiments. AFR is used to study the plasma expansion from CH foil and spherical targets that are irradiated with ~9 kJ of ultraviolet (351-nm) laser energy.

The completion of the absolute calibration of the optical response of the streaked optical pyrometer on the OMEGA laser using a NIST-traceable tungsten-filament lamp is discussed (p. 122). Laser-driven, high-energy-density-physics experiments typically have time scales of tens of picoseconds, requiring the use of a streak camera, which complicates the already formidable task of absolute calibration. The article reports a simple closed-form equation for the brightness temperature as a function of streak-camera intensity derived from this calibration.

A narrowband x-ray imager with an astigmatism-corrected bent quartz crystal for the Si He$_\alpha$ line was developed to record backlit images of cryogenic direct-drive implosions (p. 184). With backlighter laser energies of ~1.25 kJ at a 10-ps pulse duration, the radiographic images show a high signal-to-background ratio of >100:1 and a spatial resolution of the order of 10 μm. The backlit images can be used to assess the symmetry of the implosions close to stagnation and the mix of ablator material into the dense shell.

A new neutron time-of-flight (nTOF) detector was installed on the OMEGA Laser System for fuel-areal-density measurements in cryogenic DT implosions. Four gated photomultiplier tubes (PMT's) with different gains are used to study tertiary neutrons and to measure primary DT and D_2 neutrons, down-scattered neutrons in nT, and nD kinematic edge regions. The design details of the nTOF detector, PMT optimization, and test results on OMEGA are presented on p. 208.

High-Energy-Density Science

The first demonstration of magnetic reconnection between colliding plumes of externally magnetized laser-produced, high-energy-density plasmas is reported (p. 153). Two counter-propagating plasma flows are created by IR-radiating, oppositely placed plastic targets with 1.8-kJ, 2-ns laser beams on the OMEGA EP Laser System. The two plumes are magnetized by an externally controlled magnetic field. The interaction region is prefilled with a low-density background plasma. The counter-flowing plumes sweep up and compress the magnetic field and the background plasma into a pair of magnetized ribbons, which collide, stagnate, and reconnect at the midplane, allowing for the first detailed observation of a stretched current sheet in laser-driven reconnection experiments. This work was the result of a collaboration of scientists from LLE, The Fusion Science Center, Princeton University, and the University of New Hampshire.

Lasers Optical Materials and Advanced Technology

In an article on p. 97, cascaded nonlinearities in a regenerative laser amplifier are demonstrated to compensate for intracavity self-phase modulation. Without compensation, self-phase modulation limits the generation of high-quality, short optical pulses because of spatial self-focusing and spectral broadening. Experimental results obtained on two Nd:YLF regenerative amplifiers achieve a significant reduction in spectral broadening and are in good agreement with predictions from simulations performed as part of this study.

In an article on p. 135, we present evidence that the absorption of near-UV photons by HfO_2 monolayer films is reduced by up to 70% following irradiation by continuous-wave (cw) near-UV laser light. Hafnium oxide is the most frequently used high-index material in multilayer thin-film coatings for high-power laser applications; absorption in this high-index material is known to be responsible for nanosecond-pulse laser-damage initiation in multilayers. Nanosecond-pulse laser-damage tests confirm a reduction of absorption by measuring up-to-25%-higher damage.

A new collimated ion-beam–sputtering process was used to demonstrate conformal deposition of a multilayer reflector over the surface relief of a sinusoidal diffraction grating (p. 148). This process is attractive for high-laser-damage-threshold applications, with each layer acting as a diffractive element that contributes to the overall diffraction efficiency. By depositing hafnia and silica dielectric layers to enhance the reflectance of a silver film on a 1740-lines/mm sinusoidal grating, a diffraction efficiency of 93% (*p*-polarized light) and 1-on-1 laser-damage threshold of 2.66 ± 0.15 J/cm^2 (1053-nm, 65°-incidence, 10-ps pulse) have been achieved.

A programmable liquid crystal beam-shaping system was installed for a 200-mJ optical parametric chirped-pulse–amplification system front end and was used to dramatically improve the beam uniformity in the subsequent amplifier (p. 198). A highly nonuniform beam profile caused by gain inhomogeneity in the amplifier was precompensated by the beam-shaping system. The issues of running a liquid crystal device with a high-energy, ultrashort-pulse laser, such as damage risk and temporal contrast degradation, are addressed.

Omega Laser Facility Users Group (OLUG)

A capacity gathering of over 100 researchers from 25 universities and laboratories met at LLE for the Sixth Omega Laser Facility Users Group (OLUG) workshop. The purpose of the 2.5-day workshop was to facilitate communications and exchanges among individual Omega users, and between users and the LLE management; to present ongoing and proposed research; to encourage research opportunities and collaborations that could be undertaken at the Omega Laser Facility and in a complementary fashion at other facilities [such as the NIF or the Laboratoire pour l'Utilisation des Lasers Intenses (LULI)]; to provide an opportunity for students, postdoctoral fellows, and young researchers to present their research in an informal setting; and to provide feedback from the users to LLE management about ways to improve and keep the facility and future experimental campaigns at the cutting edge. The interactions were wide ranging and lively, as illustrated in the accompanying photographs.

OLUG consists of over 400 members from 44 universities and many research centers and national laboratories. Names and affiliations can be found at http://www.lle.rochester.edu/

media/about/documents/OLUGMEMBERS.pdf. OLUG is by far the largest and one of the most active users group in the world in the field of HED physics.

The first two mornings of the workshop comprised six science and facility presentations. The facility talks proved especially useful for those unfamiliar with the art and complexities of performing experiments at the Omega Laser Facility. Since the facility is constantly evolving and improving, even experienced users significantly benefited from these updates. The overview science talks, given by leading world authorities, described the breadth and excitement of HED science either being currently undertaken at the Omega Laser Facility or well within the reach of the facility with improvements or upgrades.

A total of 63 students and postdoctoral fellows, 53 of whom were supported by travel grants from the National Nuclear Security Administration (NNSA), participated in the workshop. The content of their presentations encompassed the spectrum from target fabrication to simulating aspects of supernovae.

A detailed report on the 2014 OLUG workshop may be found beginning on p. 243.

FY14 Omega Facility Operations

During FY14, the Omega Laser Facility conducted 1405 target shots on OMEGA and 699 target shots on OMEGA EP for a total of 2104 target shots [see Tables 140.III and 140.IV (p. 250)].

OMEGA averaged 11.1 target shots per operating day with Availability and Experimental Effectiveness averages for FY14 of 95.8% and 93.3%, respectively.

OMEGA EP was operated extensively in FY14 for a variety of internal and external users. A total of 638 target shots were taken into the OMEGA EP target chamber and 61 joint target shots were taken into the OMEGA target chamber. OMEGA EP averaged 7.6 target shots per operating day with Availability and Experimental Effectiveness averages for FY14 of 95.7% and 92.8%, respectively.

Per the guidance provided by DOE/NNSA, the facility provided target shots for the ICF, HED, NLUF, and LBS programs. The facility also provided a small number of shots for CEA and for the Defense Threat Reduction Agency (DTRA) (see Fig. 1). Nearly 69% of the target shots in FY14 were taken for the ICF and HED programs.

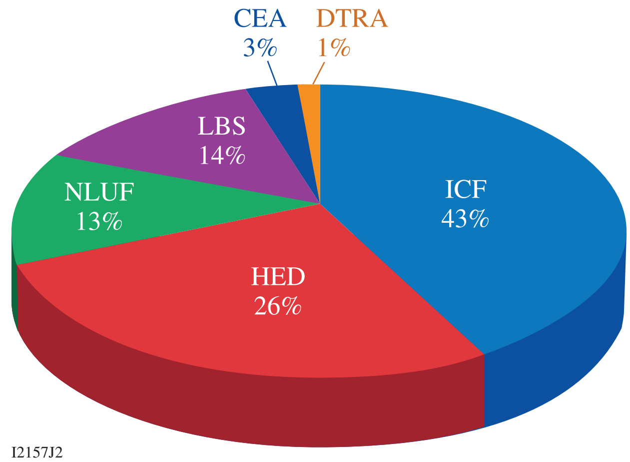

Figure 1
Chart showing the distribution of Omega Laser Facility target shots by program for FY14.

Highlights of the Omega Laser Facility activities in FY14 included the following:

- Installation of IR transmission diagnostics on OMEGA EP
- Replacement of the OMEGA laser alignment video system with a digital imaging system
- Implementation of a short- and long-pulse late-cycle wavefront control system on OMEGA EP
- Installation of OMEGA EP active shock breakout (ASBO) laser and ASBO/VISAR (velocity interferometer system for any reflector) diagnostic tune up
- Implementation of an arbitrary waveform generator on the OMEGA SSD driver
- Activation of the 4ω probe polarimetry diagnostic
- Activation of OMEGA EP beam co-propagation
- Prototype testing of the 3ω beam-timing system for OMEGA
- Qualification of ten experimental systems on OMEGA and OMEGA EP

National Laser Users' Facility and External Users Programs

Under the facility governance plan implemented in FY08 to formalize the scheduling of the Omega Laser Facility as an NNSA User Facility, Omega Facility shots are allocated by campaign. The majority (~69%) of the FY14 target shots were allocated to the ICF Campaign conducted by integrated teams from the national laboratories and LLE and the HED Campaigns conducted by teams led by scientists from the national laboratories.

The fundamental science campaigns accounted for 26.9% of the shots taken in FY14. Nearly half of these were dedicated to university fundamental science under the NLUF Program, and the remaining shots were allotted to the LBS Program, comprising peer-reviewed fundamental science experiments conducted by the national laboratories and by LLE, including the Fusion Science Center (FSC).

The Omega Laser Facility is also used for several campaigns by teams from the Commissariat à l'Énergie Atomique et aux Energies Alternatives (CEA) of France and the Atomic Weapons Establishment (AWE) of the United Kingdom. These programs are conducted at the facility on the basis of special agreements put in place by DOE/NNSA and participating institutions.

The facility users during this year included 11 collaborative teams participating in the NLUF Program; 16 teams led by Lawrence Livermore National Laboratory (LLNL) and LLE scientists participating in the LBS Program; many collaborative teams from the national laboratories conducting ICF experiments; investigators from LLNL and Los Alamos National Laboratory (LANL) conducting experiments for high-energy-density-physics programs; and scientists and engineers from CEA.

In an article beginning on p. 253, the external user activity on OMEGA during FY14 is reviewed.

1. FY14 NLUF Program

FY14 was the second of a two-year period of performance for the NLUF projects approved for the FY13–FY14 funding and OMEGA shots. Eleven NLUF projects [see Table 140.V (p. 254)] were allotted Omega Laser Facility shot time and conducted a total of 266 target shots at the facility. This NLUF work is summarized beginning on p. 253.

DOE issued a solicitation in late FY14 for FY15–FY16 experiments; in response to this call, 23 proposals were received. The proposals were to be reviewed by a technical evaluation panel in October 2014 so that DOE may decide which proposals can be accepted and receive shots at the Omega Facility.

2. FY14 Laboratory Basic Science Program

In FY14, LLE issued a solicitation for LBS proposals to be conducted in FY15. A total of 25 proposals were submitted. An independent review committee reviewed and ranked the proposals; on the basis of these scores, 14 proposals were allocated 20 shot days at the Omega Laser Facility in FY15. Table 140.VI (p. 270) lists the approved FY15 LBS proposals.

Seventeen approved LBS projects were allotted Omega Facility shot time and conducted a total of 269 target shots at the facility in FY14 [see Table 140.VII (p. 271)]. This work is summarized beginning on p. 269.

3. FY14 LLNL OMEGA Experimental Programs

In FY14, LLNL's HED Physics and Indirect-Drive Inertial Confinement Fusion (ICF-ID) Programs conducted several campaigns on the OMEGA and OMEGA EP Laser Systems, as well as campaigns that used the OMEGA and OMEGA EP beams jointly. Overall these LLNL programs led 324 target shots in FY14, with 246 shots using only the OMEGA Laser System, 62 shots using only the OMEGA EP Laser System, and 16 joint shots using OMEGA and OMEGA EP together. Approximately 31% of the total number of shots (62 OMEGA shots, 42 OMEGA EP shots) supported the ICF-ID Campaign. The remaining 69% (200 OMEGA shots and 36 OMEGA EP shots, including the 16 joint shots) were dedicated to experiments for the HED Campaign. Highlights of the various HED and ICF campaigns are summarized beginning on p. 283.

4. FY14 LANL Experimental Campaigns

In FY14, LANL scientists conducted 218 target shots at the Omega Laser Facility including 206 shots on OMEGA and 12 shots on OMEGA EP. The ICF program accounted for 40 of these shots and the HED program 174 shots. The LANL-led campaigns are summarized beginning on p. 303.

Education

As the only major university participant in the National ICF Program, education continues as an important mission for LLE. The Laboratory's education programs cover the range from high school (p. 248) to graduate education.

1. High School Program

During the summer of 2014, 16 students from Rochester-area high schools participated in the Laboratory for Laser Energetics' Summer High School Research Program. The goal of this program is to excite a group of high school students about careers in the areas of science and technology by exposing them to research in a state-of-the-art environment. Too often, students are exposed to "research" only through classroom laboratories, which have prescribed procedures and predictable results. In

LLE's summer program, the students experience many of the trials, tribulations, and rewards of scientific research. By participating in research in a real environment, the students often become more excited about careers in science and technology. In addition, LLE gains from the contributions of the many highly talented students who are attracted to the program.

The students spent most of their time working on their individual research projects with members of LLE's technical staff. The projects were related to current research activities at LLE and covered a broad range of areas of interest including laser physics, computational modeling of implosion physics, radiation physics, experimental diagnostic development, cryogenic targets, theoretical and experimental chemistry, tritium capture, electronics, image display, and 3-D virtual modeling (see Table 140.II on p. 249).

The students attended weekly seminars on technical topics associated with LLE's research. Topics this year included laser physics, fusion, holography, nonlinear optics, atomic force microscopy, electronic paper, and attosecond science. The students also received safety training, learned how to give scientific presentations, and were introduced to LLE's resources, especially the computational facilities.

The program culminated on 27 August with the "High School Student Summer Research Symposium," at which the students presented the results of their research to an audience including parents, teachers, and LLE staff. The students' written reports will be made available on the LLE Website and bound into a permanent record of their work that can be cited in scientific publications.

Three hundred and twenty-eight high school students have now participated in the program since it began in 1989. This year's students were selected from nearly 70 applicants.

At the symposium LLE presented its 18th annual William D. Ryan Inspirational Teacher Award to Dr. Jeffrey Lawlis, Chair of the Science Department at Allendale Columbia High School. This award is presented to a teacher who motivated one of the participants in LLE's Summer High School Research Program to study science, mathematics, or technology and includes a $1000 cash prize. Teachers are nominated by alumni of the summer program. Dr. Lawlis was nominated by Alex Frenett, a participant in the 2013 program. Describing his physics class, Alex wrote, "Dr. Lawlis began the year challenging the students, not spoon-feeding them information. He not only taught them to derive the necessary equations (instead of having us memorize them), but also used his background in science to make the class entertaining, as he constructed many of the lab setups himself." He proceeded to say, "Dr. Lawlis' dedication to students is rare to find. Throughout the year, you could find his students in his classroom, working one-on-one with him for help…His class, his help, and his distinctive puns somehow inspired intelligent thinking." He concluded, "This combination of intellect, support, and talent exemplifies how this man has devoted himself to his school, his community, and, most of all, his students in a way that only the best teachers ever do." Dr. Lawlis also received strong support from Mr. Michael Gee, principal of Allendale Columbia High School, who described him as "a knowledgeable person who has raised the bar of the Science Department."

2. Undergraduate Student Program

Thirty-two undergraduate students participated in work or research projects at LLE this past year. Student projects include operational maintenance of the Omega Laser Facility; work in laser development, materials, and optical thin-film coating laboratories; computer programming; image processing; and diagnostics development. This is a unique opportunity for students, many of whom will go on to pursue a higher degree in the area in which they gained experience at LLE.

3. Graduate Student Programs

Graduate students are using the Omega Laser Facility as well as other LLE facilities for fusion and HED physics research and technology development activities. These students are making significant contributions to LLE's research program. Twenty-six faculty members from five University of Rochester academic departments collaborate with LLE scientists and engineers. Presently, 64 graduate students are involved in research projects at LLE, and LLE directly sponsors 37 students pursuing Ph.D. degrees via the NNSA-supported Frank Horton Fellowship Program in Laser Energetics. Their research includes theoretical and experimental plasma physics, HED physics, x-ray and atomic physics, nuclear fusion, ultrafast optoelectronics, high-power–laser development and applications, nonlinear optics, optical materials and optical fabrication technology, and target fabrication. In addition, LLE directly funds research programs within the MIT Plasma Science and Fusion Center, the State University of New York (SUNY) at Geneseo, and the University of Wisconsin. These programs involve a total of approximately 6 graduate students, 25 to 30 undergraduate students, and 10 faculty members.

Over 323 graduate students have now conducted their graduate research work at LLE since its graduate research program began. In addition, 120 graduate students and post-graduate fellows from other universities have conducted research at the LLE laser facilities as part of the NLUF program. Over 60 graduate students and undergraduate students were involved in research at the Omega Laser Facility as members of participating NLUF teams in FY14.

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